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CENTRAL INTELLIGENCE AGENCY REPORT NO.

INFORMATION REPORT

COUNTRY USSR

DATE DISTR. 16 Nov 1948

25X1A SUBJECT Petroliferous Provinces

NO. OF PAGES 1

PLACE ACQUIRED

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PETROLIFEROUS PROVINCES OF UNION OF SOVIET SOCIALIST REPUBLICS

BY

F. JULIUS FOHS

Reprinted for private circulation from
THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
Vol. 32, No. 3, March, 1948

Approved For Release 2002/07/24 : CIA-RDP80-00926A000700030015-7

Volume 32 Number 3

BULLETIN
of the
AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

MARCH, 1948

PETROLIFEROUS PROVINCES OF UNION OF SOVIET SOCIALIST REPUBLICS[1]

F. JULIUS FOHS[2]
Houston, Texas

ABSTRACT

The purpose of this study is to give a picture of present and ultimate oil possibilities of the U.S.S.R., so they may be compared with those of the United States. Following an outline of source material for the study, a general picture of the structure and tectonics of Eurasia and Siberia is given as the background to differentiate oil-bearing from oil-barren regions. The oil and gas deposits occur in reservoir beds similar to those in the United States, ranging from Devonian to Pliocene strata inclusive. It is possible that Silurian and Ordovician will also produce, and a small amount of oil has been reported from Cambrian beds. The structure and the stratigraphic types of occurrence are also similar. A more detailed picture of each possible oil region, both productive and prospective is presented, with a comparison of their relative merits. It is shown by the map that out of 8,390,000 square miles of land-inland sea area within U.S.S.R. boundaries, 3,600,000 square miles have possibilities for the finding and production of oil; and in addition there are 400,000 square miles of continental-shelf area within the 200-meter depth limit. Of the total possible area, 1,000,000 square miles are classified as younger marine sedimentary (Cretaceous to Pliocene) deposits. Also of the total, there are 1,530,000 square miles north of the 60° parallel; hence, they are more difficult and expensive to develop.

Production to the beginning of 1947 in U.S.S.R., inclusive of Sakhalin, was 5,722,000,000 barrels; in 1946 it was 166,000,000 barrels, two-thirds of that of 1939. Total production in the United States was 34,000,000,000 barrels, while that in 1946 was 1,754,000,000, about 50 per cent more than that of 1939.

Total estimated proved reserves of the Soviets are nearly 8 billion barrels, while those of the United States are 24 billion barrels.

While the U.S.S.R. has barely begun development, having only 12,000 oil wells, the United States is well advanced with 424,000 producing wells. It will therefore require a long period of time, large capital investments, much of machine tools and other machinery adequately to develop the Soviet possibilities.

Exploration and development in the Soviet Union are being carried forward by use of latest techniques developed in the United States and elsewhere, with some new Soviet methods. It is reported that more than 2,000 geologists and geophysicists are employed at present by the Union; and engineers and technical workers are probably likewise numerous.

The affiliated countries under Soviet control are Roumania, Hungary, Czechoslovakia, Yugoslavia, Albania, and Poland, which cover an area of 427,000 square miles. These include two important

[1] Presented before the Eastern Section of the Association, at the Mining Club, New York, December 10, 1947. Manuscript received, January 16, 1948.

[2] Consulting geologist. The writer gives acknowledgment and thanks to Basil B. Zavoico for loan of Russian maps and reports; to Lewis G. Weeks for use of his basic oil estimates and loan of Russian translations prepared for the Standard Oil Company (New Jersey); to the *World Oil* for use of its library data; and to Walter J. Larke for drafting the map and assisting in computations.

basins, the Hungarian and Roumanian inclusive of the Sub-Carpathian region, which covers 130,000 square miles of prospective territory, with the Roumanian district much more important. The proved reserves are estimated as ranging from 241,000,000 to 491,000,000 barrels, with estimates for Roumania ranging from 150,000,000 to 400,000,000 barrels. Production to date is 1,459,000,000 barrels, and during 1946 it is estimated as 44,000,000 barrels. It is down 25 per cent in Roumania due to the last war, but the possibilities of developing important new production are considerable as the Roumanian basin is one of the best in Europe and similar to the Gulf Coast of the United States. The U.S.S.R. has been getting 95½ per cent of the Roumanian output because of its great need for oil, but it is reported that some of this is to be released shortly, perhaps to other East European states now that the United States has ceased exporting oil to them. Outer Mongolia and Tannu Tuva, also affiliated, have little or no oil prospects.

Lewis G. Weeks' estimate of United States sedimentary basins exploitable for oil is 1,400,000 square miles, to which he gives an ultimate estimated production of 100,000,000,000 barrels.

Comparing Soviet areas in kind with those given by Weeks for certain United States regions, and allowing for average depth of favorable sedimentary strata in each basin judged by available data, the writer obtains for the U.S.S.R. the following figures inclusive of land and continental shelf.

For the more important districts, namely, Moscow-East Russian basin, Pre-Caspian and extensions, Transcaspian, South Caucasus, and East Sakhalin, the estimated total area is 1,805,000 square miles, with sedimentary rocks totaling 2,736,000 cubic miles and having an oil-gas content of 162,000,000,000 barrels. Additionally of much more speculative character, 1,650,000 square miles, with an estimated total of 1,708,000 cubic miles of sedimentary rocks, may ultimately yield 33,000,000,000 barrels. Of this, only 6,000,000,000 barrels have been produced and about 8,000,000,000 barrels proved, leaving the balance to be found and developed, a truly stupendous task, although a large number of mapped structures await adequate testing.

It appears probable and reasonable, therefore, to conclude that the Soviet Union has within its own borders an ultimate oil reserve of at least 150–160 billion barrels, and conceivably it may approach 180–190 billion barrels. By allowing for areas under Soviet control, it is clearthat the U.S.S.R. dominates more than a third of the total ultimate oil reserve of the entire world.

Soviet Russia has ample other power resources. It is second to the United States in coal reserves. It also has abundant oil-shale deposits, which as well as the coal, may be converted to oil and gas as required. Its hydro-electric power possibilities are very large. Development of coal has been considerable, there has been some development of oil shale for both oil and gas production, and while hydro-electric development has barely begun, construction of 15,000,000 kilowatts is planned. Of its atomic-energy minerals, there is ample territory favorable for their vein occurrence in its large pre-Cambrian and shield areas; in addition, Eklund estimates one million tons of ordinary uranium extractable from Soviet oil shales and states the United States and Sweden, each has a like amount. The Soviets are resources-rich, but development-poor. This emphasizes how very great is the Soviet need for a long period of peace-time development of its great power resources, whereas the United States, through its combined individual, corporation, and government effort has reached a greatly advanced stage. Both countries can with continued development be self-contained as far as power resources are concerned for centuries to come.

This paper is a discussion of the oil-bearing provinces of the U.S.S.R., both developed and undeveloped. The map outlines the likely areas; such limits may not coincide with published studies or basinal boundaries, but they represent the writer's idea of the practical limits for exploration by evaluation of the basic geology. While large areas are eliminated as of little or no promise, heretofore considered promising by some geologists, others are added. It is 20 years since Arthur H. Redfield gave the A.A.P.G. a paper attempting by a somewhat similar approach to give an outline of the oil resources of Russia. The present study was undertaken because it seems imperative with the growing importance of the U.S.S.R. that we in the United States have a better basis for comparison of its oil-reserve areas and our own. While it is not possible to present quantitative estimates, it is possible to evaluate the relative importance of provinces and districts based on (1) extent of area outlined, (2) character of sediments, whether continental or marine, (3) thickness of sediments, and (4) extent and age of folding with consideration of effects of folding on older and younger strata.

A selected bibliography on the geology, cartography, and the oil industry of the U.S.S.R. is appended, but the principal sources on which this study is based are: the excellent geologic map of the U.S.S.R. on the scale of 1:6,000,000, published for the Moscow meeting of the 17th International Geological Congress; the tectonic map published in the *Soviet World Atlas*; the paleogeologic, paleogeographic, and tectonic maps of Arkhangelski (Eurasia), Orbruchev (Siberia), Gregory and Grabau (Asia), Leuchs (North and Central Asia), and Bubnoff (Europe), Beyschlag-Shriel-Stille (Europe). The Arkhangelski gravity and magnetic maps of Russia and southwestern Siberia were very helpful in studying fundamental elements. The papers given at the Geological Congress of 1937, geological papers from the U.S.S.R. Academy of Sciences, papers in *Oil Industry*, and in the *Prospecting Journal of Geological Institutes*, together with the studies previously published in the A.A.P.G. *Bulletin* and elsewhere, particularly those of Goubkin, Brod, Zavoico, and Marshall Kay are of great importance. Since it is not the present purpose to give details of either geology or oil fields, the appended select bibliography may be used for such references; for detailed lists of producing fields, statistics, and a good general review, the sections of the *Oil Weekly* "Oil World Atlas," covering the U.S.S.R. and affiliated states, are recommended. For a quick over-all geologic description of districts the papers in Volume I of *Science of Petroleum* are recommended. Indebtedness is acknowledged to all these sources, though no attempt has been made to specify them.

The tightening of information due to U.S.S.R. war security measures makes it difficult to get reports on the present or recent status of oil fields, including their production; this holds good for the U.S.S.R. and affiliated states as well as for states still partially under U.S.S.R. control. Though Soviet geologic reports are published, details on important new districts and extent of development have been withheld. It has been necessary therefore to use estimates of the *Oil Weekly* (now *World Oil*) on production, wells drilled, *et cetera*.

The U.S.S.R. covers half of Europe and of Asia. It has an area of 8,350,490 square miles, one-sixth of the earth's surface. The European states, Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Roumania, and Yugoslavia, now under its political control, add 426,924 square miles, and Asia, Outer Mongolia, and Tannu Tuva further add 622,744 square miles, giving the Soviets control of 18.4 per cent of the earth's surface. In comparison, the United States with 3,022,000 square miles and its territories with 597,000 square miles, give an area which is 32 per cent of that under U.S.S.R. control.

Considering its vast area, it is not surprising that the U.S.S.R. contains eight petroliferous provinces, consisting of ten major basins and fourteen minor districts which may produce oil and gas. Production has been obtained in six of the major basins and their extensions. The West Siberian lowlands, Northeast Siberia and Kamchatka provinces, remain almost unexplored. Soviet oil fields produce only 500,000–600,000 barrels daily, placing U.S.S.R. on a producing plane with the United States of 30 years ago. But Soviet Russia with its vast

basic resources, with more than 2,000 geologists and geophysicists (1945) engaged in oil exploration as well as a large staff of engineers, technicians, and workers, should speedily develop a much larger production. It is reported to have developed some new techniques and has the further advantage of those perfected in the United States and elsewhere in the past 30 years.

The strata in which oil is being sought range from Cambrian limestones through Pliocene, with the greatest production to date from Pliocene, Permian, Carboniferous, and Jurassic beds and with much new production coming from Lower Carboniferous and Middle Devonian limestone. The Silurian and Ordovician should also produce but no production is reported. Cretaceous areas are practically untouched. While there is some Jurassic production it is relatively small compared with areas underlaid by Jurassic; some of the latter are large; many of them are overlaps too undisturbed to produce; more of the deeply buried Jurassic will undoubtedly show production later. Just as Cambrian production is inconsequential in the United States, it probably will be of little importance in U.S.S.R.

Thus far, most of the production has come from anticlines and domal uplifts, only a small amount from stratigraphic traps. A marked feature of many of the developed domes in the Baku, Kuban, and East Russian basins is that they are of the elongate ellipsoidal type, cut with epi-anticlinal or transverse faults. Salt-dome production has been principally from the Emba basin, to a small extent from the Ukraine. In all important basins because of effect of shield areas and mountain uplifts, there is everywhere a plenitude of folding and faulting.

GENERAL STRUCTURE

An over-all tectonic picture of Eurasia is outlined in the following paragraphs.

In Russia proper, there is on the northwest the Fenno-Scandia shield, a large pre-Cambrian massive and positive element, on the east are the Ural Mountains of Variscan orogeny, and between lie the Moscow, Pechora, and East Russian basins, constituting part of the Russian platform. An offshoot of the Urals trending northwest is the Timan range and between it and the northern Urals lies the Pechora basin. The movement of the Urals westward toward the pre-Cambrian massive Fenno-Scandia is probably explanatory of the productive folds of the East Russian basin. The Urals, being overturned toward the west, may have important buried structures below the unconformity.

Southern Russia has two positive elements: the Voronezh block which extends eastward from the south end of the Fenno-Scandia shield and the Podolian block of the Ukraine, which is a mass of intrusives in old rocks. Between these blocks is the Ukrainian (South Russian) basin, which is the westward extension of a geosyncline extending into southwest Siberia. South of the East Russian basin is a deeper extension, the Pre-Caspian (Astrakan-Emba). Still farther south is the uplift of the Mangyslak Mountains. This is a buried uplift beneath the Caspian Sea and northeastern Kuban; north of Rostov-on-Don, it is part of the

Ukraine area. The Mangyslak uplift is a continuation of the axis of the Hissar-Tien Shan Mountains. South of this axis is the Kuban syncline which extends westward through the Sea of Azov, northern Crimea, and Bessarabia; east of the Caspian Sea, it continues as the Turkmen-Uzbec (Kara Kum) basin. On the south of this syncline are the Caucasus Mountains and their southeastward extension, the Kopet Dag Mountains from Krasnovodsk to Ashabad in Turkmen S.S.R. South of the Caucasus is the Kura River-Baku-Nebit Dag basin, which in turn is limited on its south by the Elburz Mountains of Iran.

A glance at the tectonic elements of the remainder of Siberia and adjacent territory gives the following picture.

In the Arctic are the Kara Sea and East Siberian Sea shield areas. The first shield is rimmed on the south with the Ob-Khatanga depression and the second by a slightly depressed old Paleozoic complex north of the Cherski Mountains. In north-central Siberia there is the great Anabar shield area on the east, with the Angara-Yenisei horst block on the southwest, and the shallow Tunguska River basin between. The Upper Lena-Aldan River basin occupies still shallower parts of the Siberian platform, on the south and southeast.

South and east of this in Siberia and adjacent Mongolia is a greatly folded, metamorphosed Paleozoic complex, with practically no folding in later Mesozoic beds; Weller designates southeastern Mongolia as a shield region, Gobia. In western Siberia are the West Siberian lowlands with the greatest depths of basin in a strip on the east flank of the Ural Mountains uplift, forming the Turgai-Ob River depression; farther east as part of these lowlands are the upper Irtysh and Ob River and the Yenisei River depressions. South of these is the Karaganda block or Kirghiz Steppe region, the west part of the south Siberian old Paleozoic complex.

Still farther on the south follow two important synclines: (1) the Chu River (Moyun Kum) basin bounded on north by the Char Tau Mountains and separated from the Kazakh (Kysyl Kum) basin by the Kara Tau Mountains and (2) the Kazakh syncline bounded on the south by the Hissar Mountains. Farther southwest are the several uplifts and basins of the Caspian province previously described.

In northeastern Siberia is the semi-circular uplift of the Verkhnoyansk-Kolyma-Anadyr Mountains which on its south borders a group of included basins, the deepest of which is the most westerly or Yana River syncline. This region is south of, and was pushed southward by, the East Siberian Sea shield. The Yana syncline also rims the Anabar shield. Still another basin east of the Anadyr Mountains, the Anadyr syncline has heavy Cretaceous deposits. South and east of the Stanavoi Mountains, north of Kharbarovsk, is the narrow Amur basin, probably the south extension of the Yana syncline. East of the Anadyr syncline in Kamchatka lie the Karaksky and Sreddiny Mountains, and east of these is a region of Alpine folding in Cretaceous and Tertiary beds, the southeast extension of which is formed by the Kuril Islands; similar conditions occur on the east and west

flank of the Paleozoic core of Sakhaklin Island, which is an extension of the West Pacific arcuate belt which includes the Japanese islands.

In summation, there are two great shield areas, the Fenno-Scandia shield, Voronezh block, and Podolian block on the west, and on the east the Kara shield, the Anabar-Yenisei horst-Angara shield, the Gobia shield, and the Tarim shield, while between are the great mobile basins of Russia and West Siberia, of the Lower Danube and the Caucasus region; on the south in Bulgaria, Turkey, and Iran is a great median mass, which also helps to bound and contain the mobile area, just described. This mobile region is the great oil-reserve area of Russia; east of the Anabar shield and south of the East Siberian-Chuchee seas shield is another mobile region, smaller and of less oil-productive significance.

OIL PROVINCES

The map and areal classification table present the results of this study. They give categories of provinces as to U.S.S.R. oil potentials: Primary, Secondary, Tertiary, Possible, and Doubtful. In Primary are included only those where large production is probable and depth and character of sediments warrant. In Secondary are included areas which also have considerable thickness of marine sediments so that material production appears fairly sure. In Tertiary are included some producing areas and others that will produce but thickness of marine sediments and other conditions make extent of production probably of a considerably lower order. In fourth or Possible category are placed those where conditions are generally less favorable or the geologic information is such that a higher classification is not warranted at present; there are at least two areas included in this category on the map and one of the fifth (Doubtful) category that might well belong to the third category; these three are the Yana basin, part of the Anadyr syncline of West Kamchatka, and the Ishim basin (shown in Doubtful category on the map), totalling 216,103 square miles. In the fifth category are basinal areas which, though containing seepages and structures, are of doubtful possibility for commercial oil, and do not now warrant attempts at development, especially with the large amount of more favorable territory available.

While in the attached table, land and under-water areas (water to 200 meters depth) are given separately for each district, from a practical viewpoint, they are classed in this discussion as one; there is an added development-cost increment for the under-water areas.

NORTH RUSSIAN PROVINCE

(1) *Moscow basin.*—This basin has little depth of unmetamorphosed sedimentaries excepting in its southeastern part, where two anticliinal folds appear, while a third occurs north of Yaraslavl. One gas field has been opened west of Penza. The Devonian and Carboniferous beds extend westward as overlaps on the Fenno-Scandia shield. It is in these overlaps, and particularly against closure where it is present on the larger folds where the Devonian thins, that stratigraph-

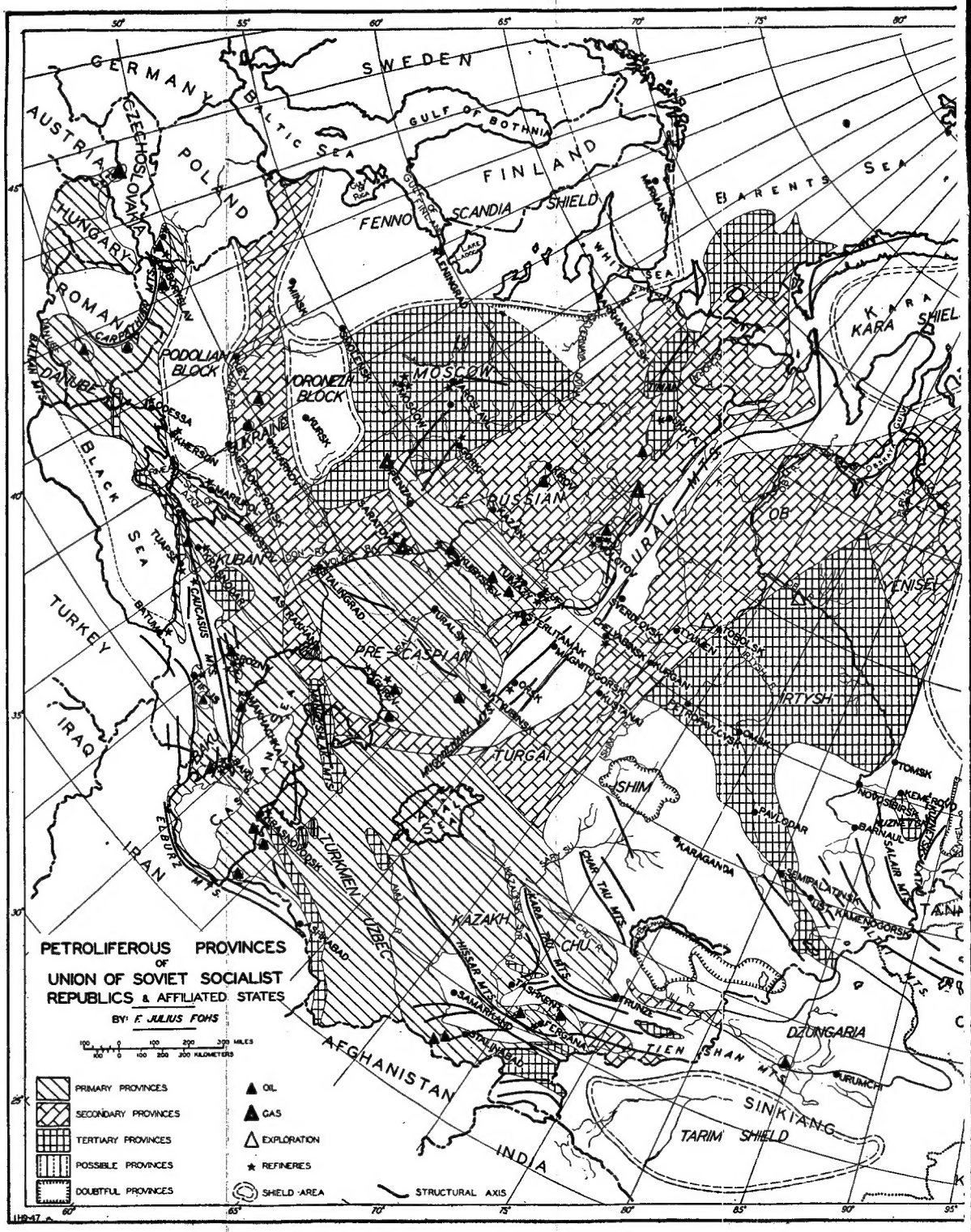
ic-type oil deposits may be sought in Lower Carboniferous and Devonian beds. North of a line eastward from the south end of Lake Onega to the Svermaya Dvina River (broken line on map) the Devono-Carboniferous section may be too thin to be worthy of prospecting, as, according to Bubnoff's interpretation, the Fenno-Scandia shield and Cambrian beds underlie this area at shallow depth; later Russian maps give, however, a different interpretation. This area should be given a low value for oil possibilities and it is excluded in the areal estimate. Oil has recently been found in the Devonian at Kasmokamsk.

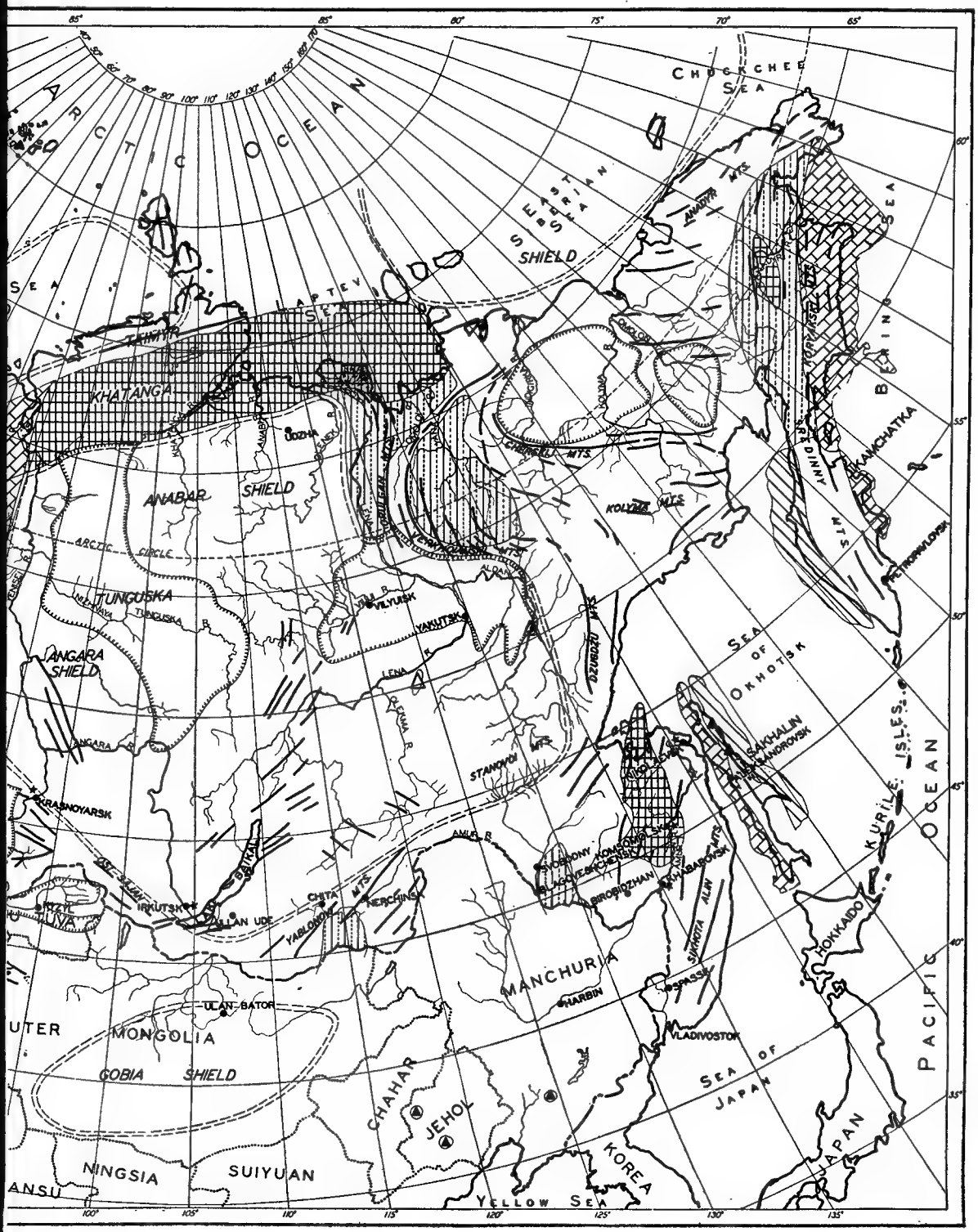
The thickness of beds in the Moscow basin, Silurian through Tertiary, averages 3,460 feet; the thickness of Cambrian beds is 510 feet. The Devonian and Carboniferous section important from an oil standpoint has a thickness of 2,000 feet, and the Permian, chiefly continental in facies, averages 350 feet.

(2 and 3) *Timan range and Pechora basin.*—The Timan range is a northwest branch of the Urals which separates the Moscow basin from the Pechora basin bounded on the east by the main Urals. The range extends northwest across the White Sea just north of Murmansk and skirts the Fenno-Scandia shield. It thereby permits the extension of the Pechora basin into Barents Sea. Production has been opened on the Timan Range at Ukta. The range exposes Devonian and older rocks, so that only limited parts of the range will be productive, and due to lack of cover only 5,000 square miles of its total area is suitable for prospecting.

The Pechora basin has Permian, Carboniferous, and Devonian rocks; production from the Devonian is assured by oil found at Severokamsk in the northern Urals. Bubnoff places a small shield area just east of the river's mouth. Folds near and paralleling both the Timan and Ural ranges should be found with production possibilities. Oil is produced at Perm and in other localities.

(4) *East Russian basin.*—With its Permian, Carboniferous, and Devonian (upper, middle, and lower) beds, this is an important petroliferous province. Its best developed oil fields are in the vicinity of Molotov and south. Its southward extension which is mapped as a primary area where the thickness of sediments, about 5,000–9,600 feet into the Devonian, is greater, includes the Kuibyshev (Samara) fields. Also, the finding of oil in the Lower Carboniferous and particularly in the Devonian limestone has been of prime importance and a factor in supplying much needed production in the last 1½ years of the war. This included the Tuimazy field which is an anticline 30 kilometers long and may cover a productive area of 75,000–90,000 acres where the Lower Carboniferous production is at 5,500 feet and the Devonian at 9,600 feet. The middle Devonian porous limestone (which does not crop out in the Urals at the east) has developed production not only at Tuimazy but also at Molotov on the north and in the Samara bend at Yablonovog at a depth of 8,500 feet. The greater thickness of Permian deposition is responsible for greater depth than in the Moscow basin. Marshall Kay gives the Permian a thickness of 4,545 feet east of Kungur, though farther north at Kizel it is only 2,575 feet. This is comparable with the thickness of 350 feet in the Moscow basin. The average covering of Mesozoic-Tertiary beds is 1,400 feet and there is at





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I. AREAL CLASSIFICATION OF PROMISING OIL PROVINCES AND DISTRICTS OF U.S.S.R.

	PRIMARY		SECONDARY		TERTIARY		POSSIBLE	
	Square Miles		Square Miles		Square Miles		Square Miles	
	Land	Water	Land	Water	Land	Water	Land	Water
1. NORTH RUSSIAN PROVINCE								
(1) Moscow basin (less north part)					250,000			
(2) Timan range					29,591*			
(3) Pechora basin and Barents Sea			101,685	21,162		57,388		
(4) East Russian basin	124,641		240,315					
(a) Saratov region			37 661					
(b) Sterlitamak region			11,657					
Total—East Russian, Pechora and Barents	124,641		391,318	21,162	279,591	57,388		
2. SOUTH RUSSIAN PROVINCE								
(1) Ukrainian basin			157,819					
(2) Pre-Caspian (Emba-Astrakan) basin	195,480	18,472	25,107					
(3) Kazakh basin	236,190	26,542			1,793			
(4) Ferghana basin	22,417							
(5) Chu River basin	43,938							
Total—South Russian 1 to 5	498,025	45,014	182,926		1,793			
(a) East Ferghana basin			14,347					
(b) Lake Issyk Kyl basin					3,138			
(c) South Ferghana (Sary Tash and Bartang rivers)					15,871			
3. CASPIAN-BLACK SEA PROVINCE								
—Trans-Caucasian basin—								
(1) Kuban (Northeast Caucasus) basin	84,289	27,797			13,450			
(2) Crimea-Sea of Azov	6,456	15,960			2,241	2,690		
(3) North Black Sea		16,140				2,152		
(4) Bessarabian (Moldavian) basin	30,308				717			
(5) Turkmen-Uzbec basin	224,175	24,211			27,977			
Total—Trans-Caucasus	345,228	84,108			44,385	4,842		
—South Caucasian basin—								
(1) Baku (Kura River) basin	20,265	10,222						
(2) Nebit-Dag basin	17,934	19,727						
(3) Black Sea basin	4,752				1,614			
Total—South Caucasus	42,951	29,949			1,614			
4. WEST SIBERIAN PROVINCE								
(1) Turgai-Ob depression			443,866					
(2) Irtysh River basin					373,030			
(3) Yenisei River depression			95,946					
Total—West Siberian 1, 2, 3			539,812		373,030			
(4) Karaganda block								
(a) Ishim basin							23,314	
(b) Kuznetsk basin					6,725			
(c) Ili River basin			8,070					
Total—Karaganda			8,070		6,725		23,314	
5. NORTH-CENTRAL SIBERIA PROVINCE								
(1) Khatanga River basin					179,340	118 3 4		
(2) Lower Lena basin							64,562	
Total—North-Central Siberia					179,340	118,364	64,562	
6. NORTHEAST SIBERIA PROVINCE								
(1) Yana River basin							83,393	
(2) Anadyr basin					10,760		111,190	21,520
(3) Southwest Kamchatka	17,934	33,177						
(4) East Kamchatka			60,347	77,295				
Total—Northeast Siberia	17,934	33,177	60,347	77,295	10,760		194,583	21,520
7. FAR EASTERN PROVINCE								
(1) Amur basin					44,835	6,276		
(2) East Sakhalin	4,483	22,417						
(3) West Sakhalin			9,594	10,939				
(4) Blagovoshchensk							16,140	
(5) South of Chita							11,657	
Grand total, all provinces	1,033,262	214,665	1,206,414	109,396	936,591	186,870	310,256	21,520

* An area of only 5,000 square miles has enough cover to prospect.

II. Areal Classification of Promising Oil Provinces in Affiliated States

	HUNGARIAN BASIN	BESSARABIAN BASIN	DANUBIAN BASIN	
	Primary Square Miles Land	*Primary Square Miles Land*	*Primary Square Miles Land*	*Tertiary Square Miles Land*
Hungary	35,868			
Austria	2,241			
Yugoslavia	9,863			
Roumania	5,380		47,076	896
Roumania Black Sea water			10,401	
Czechoslovakia	896	89		
Poland		7,263		
Bulgaria			10,491	
	54,248	7,352	67,968	896

Affiliated states total—130,464 square miles.

least 1,000 feet of Permian; under this there is 1,100–1,600 feet of Carboniferous. The upper Silurian may underlie most of this basin. The Carboniferous and Devonian may be thicker than indicated. Our only check is depth of Devonian production at Tuimazy, 9,600 feet. Already several good fields are producing, and many more should ultimately dot this region. This area has many similarities with the West Texas basin. The production due to the recent development of Devonian oil is greatly increased but is still only 20 per cent of that from the Baku fields, although no recent figures have been published; a statement suggesting an increase of 400 per cent from 1940 to 1944 makes it seem probable that it may yield 36 per cent of all production by 1950; the Russians call it "Second Baku."

The Saratov area is closely related to the Samara Bend fields. The Sterlitamak district probably has less thickness of sediments.

SOUTH RUSSIAN PROVINCE

(1) *Ukrainian (South Russian) basin.*—This is a long narrow northwest-southeast graben-type syncline extending westward from Stalingrad through Kharkov to the new Polish border. In this region only minor oil and gas fields occur, with productive salt domes at Lubny and Romney; the large gas field on a long north-south anticline, just east of Saratov, is closely related to the Kuibyshev fields.

(2) *Pre-Caspian (Emba-Astrakan) basin.*—This may well be proved the third or fourth most productive area. Its Jurassic, Permian, Carboniferous, and Devonian beds should all produce. It consists of two principal parts, the northern which contains three large arch folds and the southern which contains salt domes, salt anticlines, and a number of anticlines parallel with the Urals and their southwest extension. Wells opened are principally in Jurassic beds to depths of 2,200 feet. In the western or Astrakan part, gas has been developed. Deeper drilling is generally essential.

(3, 4, and 5) *Kazakh, Ferghana, and Chu River basins.*—Southeast of the Emba district and extending southwest from the Urals is a narrow strip which

may be uplifted or of older rocks bordering the basin and extending southwest to the Mangyslak Mountains. This strip is shown as a second-grade area with Cretaceous and deeper beds. The present study rejects Brod's interpretation of correlating this zone across the Kuban area into the Crimean-Black Sea uplift. Due south from the Urals are the Mugodzhary Mountains, of which there is a buried counterpart in the west part of the Aral Sea and underlying also the east side of the Ust-Ort Plateau. This buried uplift (formerly considered a shield area) probably dies out against, or bends southwest *en échelon* with, the Mangyslak-Hissar Mountains uplift which forms the south boundary of the Kazakh basin.

From the narrow strip, which is the southeast boundary of the Emba area, the Kazakh basin extends eastward broken only by the Mugodzhary uplift, and although covered with Tertiary and Cretaceous rocks, it is primarily similar to, but not as deep as, that of the Emba. The Ferghana Valley is the extreme east extension of the Kazakh (Kysyl Kum) basin. It is a prolific producer from a considerable number of oil pools though it is a small inter-montane basin. Production in Ferghana has been from the Eocene but Jurassic and Cretaceous will doubtless also produce, although the folds nearest Cretaceous hills have not shown anything. There has been no production reported from the main Kazakh district, though its area is both large and promising for a primary producing territory.

North of Kazakh and separated from it by the Kara Tau Mountains is the Chu River (Moyun Kum) basin which is bounded on the north by the Karaganda block. Of the old Paleozoic rocks, this region is probably less deep than the Kazakh basin and its main possibilities probably are in the Permo-Carboniferous and Devonian beds. The Turgai depression adjoins it on the northwest. The only production thus far opened is at Frunze in the extreme east corner.

(6) *Inter-Montane basins east of Ferghana*

(a) *East Ferghana.*—This is located just southeast of the Ferghana Valley. As it has Triassic at the surface with Carboniferous and Devonian beds below, it has possibilities.

(b) On the north is *Lake Essyk Kyl*, a small basin with Paleozoic and Triassic at the surface. This is southeast of Frunze, and has possibilities.

(c) Farther south of East Ferghana are the inter-montane basins of the *Sary Tash and Bartang rivers* with Paleozoic rocks and some Triassic and Jurassic, which also may have possibilities. These are immediately west of the Tarim shield area of Sinkiang province, China. This old shield area probably has only a thin cover of unmetamorphosed sediments, and is of little if any value as prospective oil area.

CASPIAN-BLACK SEA PROVINCE (TRANS-CAUCASIAN BASIN)

(1) *Kuban (Northeast Caucasus) basin.*—This Trans-Caucasus region dips north off the Caucasus Mountains and is limited on the north by the west-buried continuation of the Mangyslak Mountain uplift. Its greatest thickness of Tertiary (Pliocene through Eocene), sediments is in the Caspian just off Daghestan

and adjacent to the Apsheron Peninsula, where they reach an estimated thickness of 13,900 feet with a thinned Pliocene, but greater Miocene, while in the Tersky-Sunja region, the sedimentary thickness is 11,400 feet. Principally tested to date are the uppper 2,000 feet of Pliocene beds, though the upper and middle Miocene have better reservoir beds. As in South Caucasus, the Jurassic and Cretaceous beds also underlie this region; hence, the maximum thickness of strata is at least 25,000 feet for a considerable part of this basin.

There extends northeast from the Caucasus Mountains in the region between Krasnodar and Grozny a raised shield area with a thin covering of later rocks which for this reason is mapped third grade.

In the northwest, in the deepest part of the Kuban geosyncline, lies the Donets basin, one of the principal sources of Soviet coal. It is a closely folded basin with Devonian beds appearing on top of part of the anticlines and a heavy thickness of Carboniferous and overlying beds in the intervening narrow synclines. This is rather fully described by Bubnoff. The section is: Cretaceous-Jurassic, 2,440 feet; the Carboniferous formations reported from 16,160 to 32,340 feet, though part of this thickness may be exaggerated due to tilting of beds; and Devonian, 330 feet. Where the Devonian has ample cover and closure on the anticlines, it may yield oil. The Carboniferous section is probably too important for producing coal, or for the making of producer gas from the coal beds in place.

Principal oil production thus far has been from a stratigraphic trap at Maikop, from anticlinal structures at Grozny, and from Daghestan; gas has also been produced from the last. At Daghestan, a great many anticlines and domes have been mapped and the Caspian off-shore area should contain others with some very rich oil pools; in the same trend toward the south, an oil field was opened in 1946 in the sea about 4½ miles east of Baku.

(2) *Crimea-Sea of Azov.*—On the west are the Sea of Azov and Crimea, continuation of Kuban. Most of the Azov area should be exploitable. In Crimea, a number of fields have been opened; part of these belong to the North Crimean-Kuban basin, part to the Caucasus axis, with oil principally on the north in the former, and gas with some oil in the Caucasus extension on the south. These fields have not been proved as good as those farther east where the basin is wider. This part of the basin is limited by the Podolian block on the north, as is the Black Sea continuation of the Crimean basin.

(3 and 4) *North Black Sea and Bessarabian basin.*—The Black Sea part of this basin while sizable and wider remains as yet unexplored; this part joins the Bessarabian (Moldavian) basin on the west, and is north of the uplift shown on the map as a second-grade belt extending into Dobrudja. Farther northwest, the Bessarabian basin has the former narrow Polish sub-Carpathian basin as its extreme west extension; this narrow basin is also bounded by the Podolian block on the northeast. The oil fields at Boryslav are now principally within the new Russian boundary as the map and areal classification table show. The region between Boryslav and Odessa remains almost wholly unexplored.

(5) *Turkmen-Uzbec basin.*—This great basin is the Trans-Caspian extension of the Kuban-Daghestan syncline. It is bounded on the south by the Kopet Dag, part of the Altaids, and on the north by Mangyslak-Hissar Mountains axis. Just north of Krasnovodsk are some minor uplifts, probably northwest branches from the Kopet Dag Mountains. No production has been reported, excepting the Termez fields in Uzbec at the extreme east. This, like all Trans-Caspian basins, is covered with recent beds and considerable geophysical exploration is necessary for mapping the buried structures. Here is found a large and important off-shore Caspian Sea area. The geologic section should be proved very similar to that of the Kuban, and ultimately the production from this area, because of size and other favorable conditions, should be as great as, or greater than, any yet explored in Soviet Russia.

The Mangyslak Mountains and *échelons* at the north and Kopet Dag and its offshoots are all rated as oil-explorable areas with Cretaceous and deeper beds, as their flanks may be important for oil possibilities, and buried sections equally so.

The Kuban basin includes part of the Kerch Peninsula; the remainder belongs with the Batum-West Georgia area at the south. Here in the north Sub-Caucasus twenty-seven structures have been reported, but only a few are thus far productive. The Maikop field—stratigraphic in type—has chiefly Miocene and Oligocene beds, with a thickness on the west of 3,350 feet and on the east of 5,000 feet. Much of Maikop was ruined in the war. The Grozny oil fields, at the east, were heavily drawn on. Greater depth of exploration of some of these structures, as well as farther north from the mountain axis, where the section greatly thickens, should get results.

CASPIAN-BLACK SEA PROVINCE (SOUTH CAUCASIAN BASIN)

(1) *Baku (Kura River) basin.*—The southeast Caucasus Valley, inclusive of the Apsheron Peninsula, is the most important oil district of U.S.S.R. from the standpoint of (a) thickness and marine character of strata, (b) large number of structures already mapped, and (c) number of producing zones, known and possible. The Apsheron Peninsula strictly interpreted belongs, partly also, to the Kuban-Daghestan area. The total thickness of sediments of this region at its deepest part based on known thicknesses of exposed formations in the southeast Caucasus Mountains and in wells aggregates 29,700 feet with a range according to Goubkin, as follows: Pleistocene 136 meters, Pliocene 2,306, Miocene 1,171, Oligocene 730, Eocene 600, Upper Cretaceous 1,675, Lower Cretaceous 1,025, and Jurassic 1,370 meters. There is a fair chance of finding oil in all but the first and last formations though in the past it has come principally from Pliocene beds.

This region is bounded on the north by the Caucasus Mountains and on the south by the northwest extension of the Elburz Mountains. It narrows and thins toward the northwest, west of Tiflis. While production is thus far principally from Pliocene beds, as one approaches the edges of the basin, lower beds come within reach of the drill and with proper traps will produce through the Creta-

ceous. Several hundred structures have been mapped both on land and in the Caspian off-shore areas, and most of these should ultimately produce. From these fields has come most of the Russian oil, and though production at present is less than it was before World War II, it should eventually become larger.

As is the case in Apsheron, on the Taman Peninsula, the lower Kura Valley and, likewise, in South Georgia in the upper Kura Valley, only a few of the known structures have been developed.

(2) *Nebit Dag basin.*—Inclusive of an off-shore Caspian Sea area, this is the southeast, Trans-Caspian extension of the Baku-Southeast Caucasus basin. It differs chiefly in that the Pliocene beds are thinned on the land area and are principally a red facies with a less productive zone. The underlying Miocene should yield the principal production. The remaining stratigraphic section should be similar to that of the Southeast Caucasus. Large oil wells have produced at Nebit Dag, Chikishlyar, on Chelekin Island, and at Neftedag. Off-shore in the sea, larger Pliocence production may also appear. Here the Elburz Mountains occur on the south and the Kopet Dag Mountains on the north. The land area is somewhat less, but the land-sea area is greater than that of the Southeast Caucasus; because of thinner Pliocene, the area though primary, should have a somewhat lower reserve rating. The amount of drilling and exploration has been much less, but when fully developed the area should produce much oil.

(3) *Black Sea basin.*—The Kura River valley heads in the vicinity of Tiflis in the South Caucasus. Farther west in West Georgia, the continuation of this basin enters the Black Sea, reaching it at Batum and Tuapse; this may be designated the West Georgia wedge. It is the east corner of a very large basin, the major part of which is in the Black Sea, but which is in fact the east three-fourths of the Danubian basin of Roumania and Bulgaria. On this border, the 200-meter depth of water is reached close to shore, so that very little off-shore area is available. However, on the Dobrudja shore, off the Danubian basin, a large area occurs at drilling depth off-shore entirely untested. According to a recent report, this Dobrudja area is said to have been ceded by both Roumania and Bulgaria to the U.S.S.R. (evidently acquired for security reasons). While nothing is known directly of the stratigraphic section, the main part of this basin must have a considerably greater thickness of Tertiary beds, expecially of Pliocene and Miocene, than in the west sub-Carpathian section of the Danubian basin where the present Roumanian oil fields are located.

The stratigraphic section in the West Georgia wedge region is very similar to that in the Maikop area, but, being more basinal, the Tertiary section is greater and it should be underlain by a greater thickness of Jurassic and Cretaceous beds. Deeper drilling would doubtless uncover considerable productive oil, both in this region and in the entire east Kerch Peninsula at the north and west. Only a small amount of oil has been produced thus far and the ultimate reserves may not be large.

(4) *Danubian basin and Sub-Carpathians.*—It is necessary to point out the

salient points of this region, for though it is outside Russia, nevertheless Bessarabia and Polish Galicia, both in Russia, are part of it and if, as recently reported, Dobrudja is ceded to the Soviets, the eastern land strip of this basin at the mouth of the Danube and the off-shore area in the Black Sea are important for future oil development. The general geology and oil geology of the Roumanian and Polish Galician oil fields have been fully described by others (see bibliography). They represent primarily folds and overturned folds and diaper salt anticlines which have already produced much oil. These fields rim the Carpathians on the east from Boryslav through Bacau to Ploesti. Toward the end of the last war a salt dome was found productive somewhat farther east in the west edge of the plain. Salt domes should be found over most of the lower Danubian plain and its Black Sea off-shore extension. In Bulgaria, at the south end of the plain, there may be folds paralleling and north of the Balkan mountain range. In Bessarabia, folds along the extension of the Caucasian axis may be sought, and on the northeast other possibilities are present. The essential point is that the greater part of the Danubian basin remains untested, and the decrease in production due to war damage and excessive use of the older fields can best be remedied by new and deep exploration of the plain.

According to Ray P. Walters, 98.5 per cent of Roumanian production has come from the Ploesti or southernmost of the Roumanian fields. The big production in Polish Galicia has come from Boryslav, which has the largest of the Galician reserves. For stratigraphic sections and further details of this basin as well as the Hungarian basin, reference may be made to Walters' paper, "Oil Fields of Carpathian Region."

WEST SIBERIAN PROVINCE

This province may be subdivided into the West Siberian lowlands consisting of three related basins and the Karaganda block with some minor basins.

(1) *Turgai-Ob depression.*—This should be an important petroliferous province. There should be folds adjacent to and paralleling the Urals, with cross-folding effects extending northwest from the several fold axes of the older complex on the southeast.

(2) *Irtysh River basin and Upper Ob River extension.*—The southwest part of this depression is probably a continuation of the syncline showing in the Karaganda block on the south, but deeper and with greater thickness of sediments than in the remainder of the region. At Gankino, a test well had showings of oil and gas at 770–900 meters. It is possible that the higher plateau region exposed on the southeast may to some extent be represented under the region between the Irtysh and Upper Ob River though covered by the Jurassic sediments. This region generally is given a third-class rating.

(3) *Yenisei River depression.*—This represents a northwest syncline west of the Yenisei River, probably of some importance with folds paralleling the lower Yenisei and Angara uplifted blocks (Cambrian). The region southeast to

Krasnoyarsk is here excluded, though this interpretation may be wrong, since the area east of the 90° meridian may be basinal instead of a covered part of the Yenisei horst; only geophysical studies can decide.

The Turgai-Ob depression should have the greatest thickness of sediments. Together with the remainder of the West Siberian lowlands, it has a Paleozoic base, but on top of this perhaps Cretaceous, certainly Triassic, and Jurassic beds have been deposited; as a foredeep of the Urals, it should be a depression of some depth. No worthwhile prospecting has been done, though one borehole has shown a depth of 500 meters through the Jurassic-Cretaceous beds in the Turgai.

Little or no folding is reported in this region since the close of the Paleozoic so that the Jurassic-Cretaceous beds generally in the lowlands are probably structureless. This unconformable cover of 500–1,000 meters will require geophysical studies to locate the deeper Paleozoic folds. Accumulations are probable in beds ranging from the Carboniferous to the Ordovician.

(4) *Karaganda block*

(a) *Ishim basin.*—This small coal basin (Lake Tengiz), with Carboniferous and Triassic rocks and some intrusives, may have possiblities worthy of exploration in the Lower Carboniferous, Devonian, and Silurian strata. This is the region of the Upper Ishim River valley and lies west of Akmolinsk. It is a depression in the main Karaganda folded region.

The Balkash Sea, a part of the Karaganda block, is a large basin filled with flysch from the rocks of the Kirghiz Steppes and surrounding mountains and is underlaid principally with Silurian beds. It is of doubtful significance for oil prospecting.

(b) *Kuznetsk basin.*—This important coal basin covers a small area in the Paleozoic complex south of Tomsk. While some prospecting has been done, and oil and asphalt showings obtained, no commercial oil has been reported. Anticlinal structure occurs and doubtless deeper drilling to the Devonian and Silurian may be more fruitful.

Minusinsk is a small basin east of the Kuznetsk but is shallower and much less promising for oil, though it is coal-bearing, and is underlaid at shallow depths with Silurian and Cambrian. An adjoining small basin at the north is still less favorable, and the Ust-Kamenkorsk basin at the south, while larger, is likewise unfavorable.

(c) *Ili River basin.*—This is in the extreme southeast corner of the Karaganda block. It has a Quaternary cover over Paleozoic rocks with intrusives and probably is of little importance. It is just west of the Urumchi (Tihwa) region of northern Sinkiang province, China; in the southwest part of this basin, twenty-five oil wells were drilled by the Soviets, which at the end of the war were turned over to the local authorities. The size of this production is not large. Although China has been studied by J. Marvin Weller, not much is known of the possibilities of this basin; this is outside Soviet territory but its proximity made reference here desirable. This basin is bounded on the south by the Tien Shan range.

NORTH-CENTRAL SIBERIA PROVINCE

(1) *Khatanga River basin.*—Between the Kara Sea and Anabar-Angara shields is the Khatanga River (Taimyr) depression. This is a wide graben-type basin, rimming both the north and south shield areas. It is also a continuation of the Ob basin, which is on its southwest; on the east it becomes one with the extreme Lower Lena and Yana River basins which rim the Anabar shield on the east.

The Khatanga area has been drilled only in the vicinities of Ust Port where a slight oil showing was found near the mouth of the Yenisei River, and in the delta of the Khatanga River near Cape Nordvik. Aside from Quaternary cover, the beds are principally Jurassic, Cretaceous, Tungusian (Carboniferous), and Devonian, with some probability of being also underlain with Silurian, Ordovician, and Cambrian. The sections that can be estimated from drilling and from outcrops are not good, partly because the drilling was done on salt domes near Cape Nordvik, and partly near Ust Port where the depths were inadequate. It is possible to give what may be considered minimum thickness of strata for this basin from top of Devonian through Cretaceous with the approximate section as follows: Cretaceous sandstones, slate, and sands, as thick as 2,310 feet; Jurassic clays and sandstone, 2,145 feet; Tungusian estimated, 1,320 feet; Devonian limestone and dolomite; and rock salt with anhydrite which may be Silurian or Cambrian.

In the vicinity of Ust Port, an asymmetric anticline has been mapped and at Cape Nordvik, several salt domes have been partly explored.

This region has been given a third-class rating since conditions favor oil being found when adequate testing is done; neither sufficient tests have been made nor have they been drilled deep enough on the salt domes, and of course, other tests at the southwest have been very few, and some of these were so far south of Ust-Port as to be outside the basin.

(2) *Siberian platform*

(a) *Tunguska River basin* —This is a shallow but large basin in the west half of the central Siberian massive, lying between the Anabar and Angara shields, and bounded on the northwest by the Yenisei horst block. It has Permo-Carboniferous rocks at the surface, mostly interpenetrated with intrusives and is the second largest coal-reserve basin of the U.S.S.R., with coal from the Lower Carboniferous. The character of the Permian and Carboniferous strata makes them improbable source beds; this and the presence of the intrusives do not encourage oil prospecting, but since much of this basin is underlain with Silurian limestones, it can not be entirely eliminated as prospective territory.

(b) *Upper Lena and Aldan Rivers region.*—This, inclusive of the Vilui and Tolba tributaries of the Upper Lena, is part of the Upper Lena River basin, a shallow depression in the south half of Anabar shield-Cambrian-Silurian area. The region has been prospected for oil by Soviet geologists and some asphalt indications were found particularly in Cambrian rocks; also, evidences of Cambrian

salt beds. While mild folding occurs in the Vilui region, and also on the Tolba branch of the Lena River just east of Olekina branch, and a small amount of oil and asphalt occurs also at the southeast on the Aldan River, the region lacks ample cover to warrant further prospecting. In basins, where amply buried, these showings may point to possible Cambrian production, but because of the great age of the beds, possibilities are limited. A small production is reported from Maiya, east of Yakutsk.

(3) *Lower Lena River basin.*—A narrow basin between the Anabar shield and the Orulgan-Verkhoyansk Mountains has principally Jurassic and some Triassic beds, and these in turn are underlain probably with Silurian and Cambrian beds. The basin is here rated as fourth class, chiefly because its folds may contain Silurian and less possibly middle Cambrian oil. This has heavier cover than the Vilui region at the south; hence, it is more likely territory, yet not good enough to be rated as third class, according to a recent report, oil has been discovered and produced near the mouth of the river.

NORTHEAST SIBERIA PROVINCE

(1) *Yana River basin.*—Though classed as fourth grade on the map, because the geology is still too little known, it probably should be included with areas of possible oil. Certain facts stand out: (a) this syncline lies between the Orulgan-Verkhoyansk Mountains, back of which is the Anabar massive on the west and the Cherski Mountains on the east, (b) the rocks are principally Cretaceous, both upper and lower, in part marine, with a cover of upper Triassic and both upper and marine Jurassic, (c) there is ample folding of Mesozoic age, (d) the area has greater thickness of strata than the Indigirka-Kolyma area on the east.

Indigirka River, Kolyma River, and Omolon River basins.—North of the Cherski Mountains which are north of the Verkhoyansk-Kolyma chain, are two basinal areas in which little is known of the geology because of ice and Quaternary covering. The presence of Silurian outcrops and granitic intrusives is ample evidence, however, even though affected by Mesozoic folding, to class these areas as unpromising.

In the same category belong the Quaternary-granitic outcrops at the north, fringing the East Siberian Sea. This is part of an apron-like area south of the East Siberian-Chuckchee Seas shield, which consists of older Paleozoic rocks and was subject to Middle Paleozoic (Variscan) folding.

(2) *Anadyr basin.*—This large syncline between the Anadyr Mountains and the Koryaksk-Sreddiny Mountains thus separating the mainland from part of the Kamchatka Peninsula, is primarily a Cretaceous region subjected to post-Cretaceous folding and containing 14,000 feet of sediments, consisting of tuffs, sandstones, argillaceous sandstones, and clays, with heavy volcanic intrusions; it is graded fourth class, because of these intrusions and because we know nothing of its exploration; a small central core shown free of intrusions is graded as third class, though undoubtedly with this thickness of sediments much of the basin

may rate equally high. It lies just south of the Paleozoic beds bordering the East Siberian-Chuckchee Seas shield.

(3) *Southwest Kamchatka.*—Off the west flank of the Sreddiny Mountains is a long strip of Tertiary-Cretaceous, flanking and partly in the Sea of Okhotsh which deserves rating as a primary area, although no oil has yet been found. This is the southern continuation of the Anadyr basin, and is south of the 60th parallel. The two more northerly of the Kuril Islands and their offshore areas may be classified as an extension of West Kamchatka.

(4) *East Kamchatka.*—In the Koryasksk Mountains and eastward into Bering Sea and on the east flank of the Sreddiny Mountains north of Petropovlask is a region subjected to Tertiary (Alpine) folding, which has a number of prospects, and is entitled to rating as a second-class area. It covers a considerable region, though most of it is above the 60° parallel. There are Tertiary and Upper Cretaceous strata. High volcanic mountains define this area on the west.

FAR EASTERN PROVINCE

(1) *Amur basin.*—In the Amur province, is a narrow syncline plunging north-northeast between the Sikota Alin Mountains on the east and the Stanovoi Mountains on the northwest. Here Devonian beds reach the surface on the south but on the north first Permo-Carboniferous and then Triassic and Jurassic cover appears, together with some granitic intrusions, so that Carboniferous and more probably Devonian beds may serve as reservoir rock. This may be a southward continuation of the Yana River basin.

(2 and 3) *Sakhalin Island.*—The recent article by Leo W. Stach gives an excellent statement of the conditions in both North and South Sakhalin. In eastern North Sakhalin three producing fields have yielded about 34,500,000 barrels of oil to the end of 1939; the amount of recent production is not known. For thirteen fields, Stach estimates 3,133 acres with proved reserves of 370,000,000 barrels. This is from a length of 250 miles, mostly from a 12-mile strip on the east flank of the island, from an anticline 150 miles long, with a series of high structure developed thus far only in the Pliocene and with the deepest well about 3,500 feet. The oil is produced from the upper part of a Neocene sequence of 30,000 feet in thickness. It is most probable that other zones will be opened with depth, which will add greatly to the estimated reserves. There is little reason to doubt that exploration should show other productive fields under the sea on the continental shelf at the east within the 200-meter limit. Development was principally by the Japanese, but it has now been taken over by the Soviets.

The backbone of the island is an old Paleozoic complex. West of this complex is a Cretaceous and Tertiary belt. East of the backbone is the Neocene belt with its Alpine folds.

Tests have been drilled by the Japanese on the west side of South Sakhalin, ranging in depth from 650 to 5,275 feet. No commercial oil has been developed although there have been showings in the Neocene. The total thickness of Ter-

tiary formations according to Stach ranges from 11,480 to 36,080 feet. They are folded into a series of common gently *en échelon* anticlines trending from north to northwest. Gas seepages are also known in two instances from the Cretaceous. Stach believes there are potentialities worthy of further exploration. This area is here rated as second class, for both deeper drilling and drilling in the sea at the west should prove oil deposits of importance. On the east side of the island, Paleozoic rocks and granites are present, but farther east on the continental shelf, a part of the area must be underlain with Tertiary worthy of development. Sakhalin may well be proved to be a very large oil reserve.

(4) *Blagoveschchensk area.*—In the upper Amur River Valley, a small fourth-grade basinal area has been hollowed out of the old Paleozoic complex. This has a Paleozoic base with a covering of Jurassic and Triassic beds, and in the south and deeper part some Cretaceous beds; there may also be igneous intrusions such as occur surrounding it. South of the Amur River are Manchuria and the Hsiaokhiang Shan Mountains.

(5) *South of Chita.*—A small basin, the extension of an east Manchurian basin, with Triassic, Jurassic, and Cretaceous, and intrusive rock at the surface, occurs upstream from Blagoveschchensk on the east side of the upper Amur River. It is a small hollow carved out of the Paleozoic-granitic complex with minor possibilities.

SALT-DOME PROVINCES

Soviet Russia has at present three provinces in which salt domes occur.

(1) *Ukraine.*—In the Ukraine (South Russia) basin there are three salt domes, those of Lubni, Poltava, and Romney (only Romney and Poltava have production), and others are possible. With these, some oil and gas are associated, but they are of minor importance since this basin does not contain beds much deeper than the Devonian and though Silurian be may present, the salt may have originated in either Silurian or middle Cambrian beds.

(2) *Khatanga Bay.*—The Khatanga Bay (Cape Nordvik) region is part of the Khatanga depression. Here twelve (twenty structures reported) salt domes have been found. The salt is considered Silurian or may be middle Cambrian in age. Oil showings occur, but no oil has been found commercially productive; three of the salt domes have been outlined by test core-holes. The domes are piercement with varying amounts of cover; deeper testing to reach the Tungusian (lower Carboniferous) series is recommended, and the Silurian also warrants testing.

(3) *Emba-Astrakan district.*—This has a large number of salt domes as well as some salt anticlines. Oil is produced from both Jurassic and Permian beds and the chances favor production from the Carboniferous, Devonian, and upper Silurian limestones when sufficiently deep tests are drilled. Additional salt domes, some of them deeper-seated, may be expected in the northern Caspian Sea.

(4) *Kuban-Turkmen and Baku.*—The two basins on the south, both the Kuban-Turkmen and the Baku, may be proved to have salt domes in the at-present non-explorable deeper areas of the Caspian Sea, since the depth of cover is favor-

able to such occurrences, though this will depend on the presence of Silurian or Cambrian salt, which may be absent if this was a land area in those periods.

(5) *Vilui and Upper Lena-Aldan.*—Cambrian salt is known to occur in the Vilui and Upper Lena-Aldan region, but conditions there are not favorable to productive salt domes.

OIL PRODUCTION, RESERVES, AND ULTIMATE POSSIBILITIES

PRODUCTION

The following table gives total production to date and also for the year 1946. Regression of production due to the effects of World War II was particularly noticeable in Roumania, Russia, and Poland. In Roumania, production was 45,048,000 barrels in 1939 against estimated 32,450,000 barrels in 1946. In Soviet Russia (except Sakhalin) it was 216,886,000 barrels in 1939 against estimated 160,000,000 barrels for 1946. In Poland it was 3,900,000 barrels in 1939 against estimated 800,000 barrels in 1946; part of this great divergence is due to Soviet Russia having taken over such a large part of the Polish Galician oil fields.

PRODUCTION IN U.S.S.R. AND AFFILIATED COUNTRIES
(From 1946 Yearbook-Forecast Number (February, 1947)—*Oil Weekly*)

Inclusive Years		*In Thousands of Barrels*	
		Total to Date	*1946*
1933–1946	Albania	9,923	725
1919–1946	Czechoslovakia	3,803	188
1935–1946	Austria	34,135	4,500
1937–1946	Hungary	3,291	5,220
1857–1946	Roumania	1,130,053	32,450
1863–1946	Russia (except Sakhalin)	5,655,712	160,000
1921–1946	Sakhalin	66,240	6,000
1874–1946	Poland	277,644	860

From another source the total 1945 production of Soviet Russia, inclusive of Sakhalin, was 143,500,000 barrels—the great bulk being produced from Baku. One reason for the failure of the Second Baku to produce more was the decline at the important Ishimbaero field. According to this report almost 70 per cent still comes from Caucasus fields, and 14 per cent from the Second Baku.

United States production in 1946 was 1,731,889,000 barrels as against U.S.S.R. production of 166,000,000 barrels, inclusive of Sakhalin, which is less than one-tenth that of United States; and whereas Soviet production declined one-third since 1939, the United States production is more than a half billion barrels greater annually.

ESTIMATES OF PROVED RESERVES

Of proved oil reserves, the *World Oil* gives the total for the world at 63,187,037,000 barrels with United States 24,194,587,000 barrels and Soviet Russia 7,590,000,000 barrels, inclusive of Sakhalin. If Stach's estimate on Sakhalin of 370,000,000 barrels is used and 7,500,000 barrels for Soviet Russia, the total would be 7,870,000,000 barrels; probably this figure more nearly reflects present status than L. F. McCollum's recent figure of 5,700,000,000 barrels. For

Soviet-controlled Albania, Czechoslovakia, Hungary, Poland, and Roumania, the proved reserves would be 241,000,000–491,000,000 barrels depending on the estimate for Roumania of 150,000,000–400,000,000 barrels; most of the Roumanian estimates have been of the latter order. Logan gives 13,051,450,000 barrels as the interest in foreign oil reserves held by American companies.

The principal Soviet authority on oil reserves was I. M. Goubkin. He reported estimates in 1937, 1938 and 1939. He has classified reserves as "industrial" probably equivalent to our "proved," with two other categories of "supposed" and "possible." The 1937 report was detailed as to districts and categories, and from this we find him giving prime importance to the South Caucasus and Trans-Caucasus, allotting seven-eighths of his "industrial" to these areas. If we add the last two of his categories together and call them "speculative," we would get the following relative groupings: South Caucases first place, with Pre-Caspian and East Russian basins rated about equal and each at a little more than half that for South Caucasus. Still lower values are given the Trans-Caucasus and Sakhalin, with the other districts making up the remainder. It is probable that with the finding of deeper oil, he would now give East Russia and the Pre-Caspian a somewhat higher rating. In 1938, he raised his industrial estimates about 730,000,000 barrels to 7,194,000,000 barrels; this after Lower Carboniferous production was found at Tuimazy; his over-all estimate was about 63,146,000,000 barrels. In 1939 his estimate of "explored and visable" was 2,420,000,000 metric tons which may be translated as 17,641,800,000 barrels.

In a 1940 estimate of ultimate reserves covering the entire Soviet Union, 25 per cent was assigned to South Caucasus and Baku fields, 14 per cent to the East Russian basin, Emba basin 22 per cent, and Trans-Caucasus 19 per cent. This estimate is more conservative than that of Goubkin. It is also reported that there has been a considerable increase above the figures then given as a result of developments during the war years. Goubkin's total figures for speculative possibilities are not out of line.

The most optimistic of any of our American estimates has been 8,500,000,000 barrels proved.

Gas is reported both in separate reservoirs and accompanying oil production from most of the oil districts, and while large amounts were flared in the early days just as in our own country, now gasoline absorption plants have been built to save the natural gas-gasoline, and a considerable gallonage is produced. Gas in the Baku region is principally from oil fields; it contains 73–95 per cent of hydrocarbons, with carbon dioxide and nitrogen making up the remainder. Of fields principally gas, there may be mentioned those of Saratov (where a large number of potential structures are reported still to be developed), Daghestan, Shugarov, and Astrakan.

In 1940, Russian geologists estimated available gas reserves at 1.8 trillion cubic feet of which about one-third was from gas fields and the remainder from oil fields. Inclusive of possible reserves, their estimate was 32.7 trillion cubic feet, about half from gas fields. A more recent estimate of the Daghestan gas reserves

alone is reported as given by Kovalevsky at 3 billion tons. To what extent the proved gas has been increased since 1940 is unknown. United States proved gas reserves as of the end of 1946, estimated by the American Gas Association, are 160 trillion cubic feet. In the writer's estimates of oil reserves herein there is no effort to separate gas reserves.

SUMMARY OF CLASSIFICATION

Relative importance of districts.—In any attempt to judge relative values it is necessary to weigh subdivisions of provinces, basins, and districts, because deposition may differ sufficiently as, for example, west of the Caspian Sea a better set of conditions appears in all basins than in the Trans-Caspian region, chiefly because of greater depth of marine deposition. West Georgia and West Kuban regions appear less favorable than farther east, and for the same reason. Another example is the west coast of Kamchatka classed as primary, where conditions are not yet amply known to rate it with other primary localities. In second class, the south part of the East Russian basin is more important than the Pechora basin. Likewise, Eastern Russia may have a higher value than the Turgai-Ob and Yenisei basins, or than the Ukrainian. The Pre-Caspian basin may rate somewhat higher than that of East Russia or Kazakh, while Chu River is probably less important. The Danubian basin is more important than the Bessarabian-North Black Sea, Crimean-Azov syncline, and particularly more so than the Hungarian. The East Kamchatka region may well be proved of as great importance as the East Russian basin. The East Sakhalin coastal plain is small but will be highly productive. Perhaps the entire north part of the Moscow basin should not be counted. Among fourth-class areas, the Yana and Andyr basins especially offer possibilities.

The principal Soviet development thus far has been in the Southeast Caucasus, in the Trans-Caucasus, in the Emba district, and the East Russian basin, with the Trans-Caspian, Ferghana Valley, Sakhalin (Japanese development), and a lesser amount in the Ukraine and Uzbec. Hence, not only is there the room for intensive and deeper developments, but very great districts remain untouched.

Above 60° Parallel.—Considerable territory in the second, third, and fourth categories falls above the 60th parallel, as follows.

	Square Miles
Secondary	753,000
Tertiary	478,836
Possible	276,183

Of these areas, those of the Pechora basin, the Ob and Khatanga depressions, Yana basin, Anadyr basin, and Kamchatka region are the more important. Enough work has been done by the Russians (and some by Americans in Alaska), to prove that operations are practical even though ice and cold increase the cost and lower the efficiency. The inefficiency can be partially eliminated with greater experience. Certain it is that development of these areas may be deferred and the U.S.S.R. still have very large oil territories to develop.

Deep-sea areas.—In addition to the figures given in the table, the following deep-water areas exist, and are too deep for exploration under present conditions. Primary: (1) North Black Sea, 1,345 square miles, (2) Black Sea extension of Danubian basin, 77,295 square miles, (3) Trans-Caucasus section, Caspian Sea, 19,625 square miles, and (4) Baku section, Caspian Sea, 28,056 square miles. The total is 126,321 square miles primary; and in Black Sea areas there are 3,586 square miles of tertiary grade.

Younger beds.—Since Pratt has indicated that 80 per cent of the world's production has come from younger formations, Cretaceous through Pliocene, it is important to note that the areal extent of such basins, counting only those that have been affected by Mesozoic and later folding, is 1,007,000 square miles.

Categories and basins.—In any estimate of the ultimate oil-reserve possibilities of the U.S.S.R. it is clear that the total areas worthy of development are very large compared with that of any other nation, and since the basic geologic conditions do not greatly differ from those of the United States, we must agree with Wallace Pratt who in a Kansas University lecture in 1941 said of Russia: "Still largely undeveloped, indeed, largely unexplored, they (the oil resources) are nevertheless without question potentially far greater than those of any other nation." This is fully supported by the following summary figures of prospective areas based on the present writer's map and the areal classification table.

The U.S.S.R., out of a total land and lake surficial area of 8,390,000 square miles, has 3,625,425 square miles of prospective oil territory inclusive of 126,971 square miles of under-water lake areas; in addition, there are 406,480 square miles off-shore in seas and oceans of prospective territory, and finally there are 93,000 square miles worthy of further investigation belonging in the fourth group. This gives an over-all land and sea prospective sedimentary area in excess of 4,000,000 square miles. In European affiliated and controlled countries there is an additional, chiefly primary, area of 130,000 square miles.

Divided into the principal categories shown on the map, there are: Primary, 1,248,727 square miles; Secondary, 1,378,578 square miles, Tertiary, 1,164,986 square miles, and selected from the fourth group, 239,417 square miles.

If we summarize contiguous areas of the principal synclinal and monoclinal stratigraphic areas, we find single basins and their genetic extensions very large as is shown by the following figures.

	Square Miles	*Categories*
Moscow and Timan	255,000	(3rd)
Pechora-East Russian	536,121	(1st & 2nd)
South Russian province	543,039	(1st)
Trans-Caspian basin	478,663	(1st & 3rd)
South Caucasian basin	72,900	(1st; in addition large deep sea areas)
West Siberian province	992,645	(2nd & 3rd)
Khatanga graben	287,700	(3rd)
Northeast Siberia (Yana and Anadyr basins)	216,000	(3rd or 4th)
Kamchatka	188,753	(1st & 2nd)
Sakhalin, East	26,900	(1st)
Sakhalin, West	21,533	(2nd)

For comparison, the Gulf Coast-Mississippi embayment region inclusive of northeast Mexico, land area only, covers 190,000 square miles and the West Texas-New Mexico Permian basin 50,000 square miles. Those Soviet areas most comparable with the Gulf Coast are the Trans-Caspian and South Caspian basins which were intercommunicating in the Caspian Sea, while conditions in the East Russian basin parallel those of the West Texas basin.

Lewis G. Weeks advises the writer that his estimates of ultimate oil in sedimentary basins have two principal bases: (1) reserves of special basinal areas on an areal basis, and (2) oil content per cubic mile to a maximum depth of 20,000 feet, but only to the average estimated thickness if of less depth; where depth is greater than 20,000 feet it is ignored. He makes use of known production and estimated reserves of certain United States areas, his estimates in barrels of oil per cubic mile being as follows.

	Barrels
Michigan and Kentucky basins, each	6,000
Illinois	35,000
Texas Gulf Coast (to the Cretaceous boundary)	60,000
Oklahoma	70,000
California	180,000
Texas as a whole	38,000

He states larger concentrations favor mobile basin types. For producing basins of the United States, he used an average figure of 30,000 barrels. He further states that in well developed basins the percentage of total basin area that will be proved productive may vary from less than ½–1 per cent to as much as 5 or 6 per cent. Such percentages and per-acre yields, as well as the productivity per cubic mile vary in accordance with certain factors. Among these are the class of basin, degree of mobility, the deposition bottom environment and history, the structural history, type and degree of porosity development, portion or elements of the original basin represented today, and so on. Over large areal units ranging up to continental proportions, the errors in estimating small areas or basins will tend to iron out.

For the sedimentary basins of the world, he gives: area, 15,000,000 square miles; mass 20,000,000 cubic miles; and content, 600 billion barrels of oil.

His estimate of United States sedimentary basins exploitable for oil is 1,400,000 square miles and 2,000,000 cubic miles, to which he given an ultimate estimated production of 100,000,000,000 barrels.

As United States production has been 34,000,000,000 barrels and proved reserves are estimated at 24,000,000,000 barrels, there remain speculative reserves of 42,000,000,000 barrels to be found and intensively developed.

Weeks' Russian equivalent is 1,200,000 square miles in European Russia plus 2,500,000 in Siberia. These are somewhat different basinal areas from those the writer has outlined. His estimate for ultimate reserve is 160,000,000,000 barrels, based on a total volume of 5,000,000 cubic miles at 32,000 barrels per cubic mile. Of this, 2,000,000 cubic miles are allotted to European Russia at 50,000 barrels per

cubic mile and 3,000,000 cubic miles to Siberia at 20,000 barrels per cubic mile. For continental shelves, he would allot additional value for both nations.

Comparing Soviet areas in kind with those given by Weeks for certain United States regions, and allowing for average depth of favorable sedimentaries in each basin judged by available data, the writer obtains for the U.S.S.R. the following figures inclusive of land and continental shelf: for the more important districts, namely, Moscow-East Russian basin, Pre-Caspian and extension, Trans-Caspian, South Caucasus, and East Sakhalin, a total area of 1,805,000 square miles with sedimentaries totaling 2,736,000 cubic miles and having an oil-gas content of 162,000,000,000 barrels. Additionally of much more speculative character, 1,650,000 square miles, with an estimated total of 1,708,000 cubic miles of sedimentary rocks, may yield an ultimate of 33,000,000,000 barrels. Of this only 6,000,000,000 have been produced and about 8,000,000,000 proved, leaving the balance to be found and developed, a truly stupendous task, although a large number of mapped structures await adequate testing.

It appears likely and reasonable, therefore, to conclude that the Soviet Union has within its own borders an ultimate oil reserve of at least 150–160 billion barrels, and it may conceivably approach 180–190 billion barels. If allowance is made for areas under Soviet control, it is clear that the U.S.S.R. dominates more than one-third of the total ultimate oil reserve of the entire world.

In the August, 1947, A.A.P.G. *Bulletin*, the writer pointed out that the Middle East ultimate reserves should be of the order of 100,000,000,000 barrels; it may reach 130,000,000,000 barrels. Its chief advantage is the great thickness of producing strata so that large production may be obtained from a smaller number of wells and cost per barrel will be very low.

SOVIET AFFILIATED AND CONTROLLED COUNTRIES

Of the Danubian basin and contiguous sub-Carpathians, a fuller statement was given previously, since part of this is now Soviet owned, the U.S.S.R. having taken over the greater part of the Polish Galician oil fields and Bessarabia. What remains in Roumanian hands is still one of the most important producing provinces of Europe; the basinal part is practically untested, and likewise its southern part which is in Bulgaria. This basin including offshore area in the Black Sea covers 75,000 square miles.

The Hungarian basin covering 55,000 square miles has been only partly developed, although it is not as important as the Danubian. In the southeast, the Transylvanian section has principally gas fields. The north part in Hungary and the most westerly area which is in Austria contain some productive oil fields.

South of, and adjacent to, southeast Siberia are Tannu Tuva and Outer Mongolia. In Tannu Tuva is a basinal area covering most of this small state. It is bounded on the north by the West Sajan and the Ost Sajan Mountains. It is made up chiefly of older Paleozoic rocks and probably is of small prospective value.

On the south, in adjoining Outer Mongolia, are smaller graben valleys before

the Mongolia Altai Mountains are reached, but they are narrower and probably of even less value. On the east, and covering much of the country, is the Gobia shield. The stratigraphic studies of Berkey, Morris, and others make it seem doubtful if there are any important prospective oil areas in Outer Mongolia.

Thus, there are under control of the Soviet Union an additional 130,000 square miles of oil exploitable territory in eastern Europe which will ultimately yield large reserves, but is particularly important to the Union now because of her need for immediate production.

MAKING ULTIMATES EFFECTIVE

In the United States large sums of money with devoted application of a very large group of risk-, incentive-, and pioneer-minded corporations and individuals, as well as a period of 80 years, were necessary to develop our oil reserves. United States corporations and individuals have more than 17 billion dollars invested, and a program calling for the expenditure of 10 billions more of capital over the next 5 years for our own and foreign fields. In the United States alone there are 424,000 producing oil wells, a large number of gas wells, and many thousands of dry holes. The last are a necessary part of the cost of finding and developing oil fields. In 1946, there were completed 16,169 oil wells, 3,303 gas wells, and 8,515 dry holes. The average depth of hole in United States in 1946 was 3,342 feet. Deep drilling 12,000 feet and deeper, is only a matter of 10–12 years in the future.

In contrast, development is very young in the U.S.S.R., which as already stated, is 30 years behind the United States. The Soviets have only an estimated 12,000 producing wells, and are thought to have completed in 1946 about 800 oil wells according to the *Oil Weekly*. Until 1944, there were 117 fields discovered, of which 34 were found after 1940. The present reported total is 172, of which 36 are in Asia. Besides, the average depth drilled is much less than in the United States. Outside of Baku and occasionally elsewhere, with maximum producing zones to a depth of 10,200 feet, not even medium-depths wells (5,500–9,600 feet) were drilled before 1944, and most were 2,000–3,500 feet.

The laying of Soviet oil and gas lines was speeded by the last war. Greater use of gas by city and industry is now being made, but still it is only a beginning. A start has been made in reallocating and building new oil pipelines to speed better distribution, but only a start since the total mileage as yet is small. There is great use of tankers on the Caspian and Black seas; also on rivers and new canal net-works.

Due to decreased imports both from affiliated countries and the United States, as well as lowered or inadequate production at home, Robert S. Allen recently reported that a reorganization of the personnel has been ordered of the Russian oil trusts to increase Soviet production. It has been elsewhere reported that Roumania is preparing to divert part of its output from the 95½ per cent being sent to Russia. Part of the diversion may be needed by other countries under Soviet control from whom also United States oil imports have recently been

cut. Although the input of water is a conservation measure, the injection of about 58,000 barrels daily into the Tuimazy oil reservoir is evidence of the heavy pulling from Soviet wells.

While the U.S.S.R. has great potential oil and gas reserves, it is clear that a period of many years, large expenditures, greater allocations of steel and machine tools, and a much increased technical personnel are required to develop them. This requires diversion from other industries and especially from the military, which apparently still absorbs much of the heavy industry. Besides, Soviet industry as a whole has heavy rebuilding tasks due to Czarist backwardness and two great wars, not to speak of the large new developments necessary in consumer and other lines to give its people a modern living standard and permit the country to rank as its size, resources, and number of people warrant as the second greatest nation. It will require much expenditure and a long peacetime effort to industrialize the Soviet Union.

OTHER SOURCES OF POWER

Oil is the most mobile of power sources and it is clear that Soviet Russia's ultimate store is large. On what other power sources can she depend?

Her coal reserves, according to George B. Cressey, amount to 1.654 trillion metric tons, being only second to those of the United States which are estimated at 2.889 trillion tons, with China in third place. According to C. A. Carlow, these estimates require downward revision, and are probably too high. The Soviet coal is well distributed from the Moscow basin on the west to Khaborovsk in the Far East. In 1940, there were mined 164.6 million metric tons. Some producer gas is reported being made by burning coal in place in the Donets basin. Two plants for hydrogenation and one for synthetic petrol are to be built by the Soviets. There can be no question that ample power sources are available for centuries to come for both the Soviet Union and the United States within their own boundaries, now that gas and oil products can be produced from coal on an almost competitive basis with that from oil. The initial drawback is the high capital investment necessary for building the plants.

In the U.S.S.R. there is an abundance of bituminous and kerogen (oil) shales in formations principally of Ordovician, Upper Devonian, Upper Carboniferous, and Upper Jurassic age. It is estimated this amounts to 15 billion metric tons from the following districts: Leningrad, Moscow basin, East Russian basin, Ural Mountains, and Pre-Caspian basin. With recoverable oil at only 10 gallons per ton of shale, it has been estimated that this tonnage would yield 3.5 billion barrels of oil minimum, when fully processed. In addition other sources of oil shale are the Kuznetsk, Minusinsk, and Donets basins, Ferghana Valley, and Lake Baikal region.

Major Cadman reports the world's proved reserve stock of kerogen and bituminous shales at one million million tons. He reports Esthonian bituminous shale to contain 48–86 gallons of oil per ton, and the Germans during their occu-

pation set a goal of recovering 12,000,000 barrels of oil annually from this source. Three new shale refineries are now under construction there and gas from them is to be piped to Leningrad; these refineries will supply chemicals, plastics, and sulphur as by-products.

Esthonian bituminous shale is interbedded with Ordovician chalk beds, the shale having an aggregate thickness of two meters, and underlies the Baltic coastal strip in a width of 25 miles. In this study, it is estimated that it represents a tonnage of more than 16 billion metric tons with an oil content of the order of 16 billion barrels. In the Leningrad district the northeast extension of the same beds is estimated in excess of 2.5 billion tons. Another principal source of Soviet bituminous shales is of Jurassic age and occurs in the Lower Volga region and also exceeds 2.5 billion tons. Large-scale stripping operations are necessary for mining these shales. From recent reports, gasoline from shale can be produced at 8–10 cents per gallon and at a slightly higher cost than from coal and oil, based on present oil prices.

Hydro-electric power potential is also very large in the Soviet Union according to Cressey. Based on stream flow available, half the time (some of the projects are affected by their far-north position) potential hydro-electric power amounts to 280,690,000 kilowatts. The projects under development and proposed cover 15,000,000 kilowatts on the Volga, upper Yenisei, and Angara rivers, and in addition there is the plant on the Dneiper River which pre-war had a 900,000 kilowatt capacity. The aggregate capacity at present is not known, but in 1940 it was 2,500,000 kilowatts.

The United States had at end of 1945 an installed hydro-electric capacity of 15,000,000 kilowatts. Our total hydro-electric and otherwise-derived electric-power capacity are in excess of 65,000,000 and will exceed 70,000,000 kilowatts before the end of 1948. It will require heavy expenditures and much time for an equal development in the U.S.S.R.

Of atomic-energy sources in Russia very little is known. It is evident from the map showing shield and pre-Cambrian areas that there are ample regions for uranium vein prospecting. Recently, Major Cadman quotes Joseph Eklund of the Swedish Geological Survey as reporting Swedish oil shale already mined as containing 0.1–1 per cent of uranium and estimated to contain 50,000 tons of uranium; he further estimates Swedish oil shale averaging 0.2 per cent uranium will yield 1,000,000 tons of uranium and states that the United States and Soviet Russia each have a like quantity available from oil shales; each nation has greater quantities if lower uranium content proves recoverable. Extraction cost is estimated at 200 kroner ($55.70) per kilo, or about $22 per pound of ordinary uranium. One pound of fissionable uranium is able to develop as much energy as 10,000 tons of pure coal, but only one pound of fissionable uranium is available to each 140 pounds of uranium metal. It is impractical at present to compare the equivalency of coal and uranium and it will be some years yet before practical

uranium power plants are in operation. It seems possible that Soviet purchases are being made from Sweden.

From a good source, it is learned that very little is being exported from Joachimstal in Bohemia to Soviet Russia, and that another locality, Piestamy, is considered favorable for prospecting. In Saxony (east Germany) now under Soviet control, 8,800 workers are mining the lean uranium veins; none is being obtained from Marienbad where 1,200 additional workers are engaged. In a recent Russian paper on rarer metals, no mention was made of atomic-energy sources.

The world's pre-war known large commercial vein deposits of uranium are only those of Great Bear Lake in Canada and of Katanga, Belgian Congo, with a number of other small scattered deposits. If, as Eklund points out, it is practical to recover uranium from certain oil shales, it may be that further research will prove this an important resource in the United States and elsewhere.

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